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The transparency of the atmosphere over India

N. V. IYER

Meteorological Office, Pune

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सार — भारत के ऊपर बायुमण्डल (q) की पारदर्शिता का भारत में भूमण्डलीय (G) तथा विसरण सौर विकिरण (D) मापों से अध्ययन किया गया है। D/G तथा D/G—D अनुपात छितराव दर्शति हैं और इनका भी सभी केन्द्रों के लिए अध्ययन कर लिया गया है।

ABSTRACT. The transparency of the atmosphere (q) over India has been studied from global (G) and diffuse solar radiation (D) measurements in India. The ratio D/G and D/G—D which indicate the scattering have also been studied for all the stations.

1. Introduction

A systematic study of the transparency, of the at mosphere to solar radiation (q) from the global (G) and diffuse (D) radiation measurements in India has been made. The variation of 'q' with respect to time and season for all the stations in India have been presented. The scattering generally represented by the ratio D/G and their variation with time and season have also been discussed. Since D is a part of G, it is felt that the ratio $D/G—D$ may represent the scattering better. Therefore, these ratios also have been included in the study.

Further, variation in the general depletion of radiation is due to the prevalence of aerosol, water vapour and other pollutants in the atmosphere. Therefore, the increase in these, will naturally result in a decrease in incoming solar radiation and so the transparency. The ratio D/G and $D/G—D$ will then increase. The values could thus be useful in the study of air pollution as a qualitative estimation of the variation of atmospheric particles comprising of aerosols, pollutants etc. The study of pollution is of late gaining significant importance.

2. Data

The individual measurements of the intensity of solar radiation would have been more accurate for the purpose. Only spot readings of this parameter are possible either near about fixed hours or constant atmospheric depths. Hence, the global and diffuse solar radiation data obtained from continuous records have been used for the present study. The departmental publication *'Radiation short period averages'* based on data from 1957 to 1975, contain global and diffuse radiation data on cloudless days. Moreover, since clouds absorb, reflect and scatter radiation energy received, the variation of the depletion of solar radiation in the atmosphere

is very wide in the presence of clouds. Hence the data on cloudy days is not suitable for the work.

3. Computation

It is very well known that

$$G—D=I \sin h, \text{ where,}$$

'G' is global solar radiation

'D' is diffuse solar radiation

'G—D' represents the component of radiation from the sun received on a horizontal surface on the earth.

'I' is the intensity of solar radiation received at earth on a surface placed perpendicular to the sun's rays. 'h' is the solar elevation, which is determined by the formula $\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t$ where, 'ϕ' is the latitude of the place. 'δ' is the declination of the sun and 't' is the hour angle.

As per the formula by Bouguer

$$I = I_0 \, q^m$$

where I_0 is the extraterrestrial intensity of solar radiation. q is the transmission coefficient and 'm' the airmass. This law is valid strictly only for monochromatic radiation. This is, however, used as an approximate extension.

The solar constant has been taken as 1.98 cal/cm²/min. This has been corrected for sun earth distance to determine I_0. 'm' is the airmass or the thickness of the atmosphere when compared to that of an overhead sun, and is greater than one, for a station at sea level.
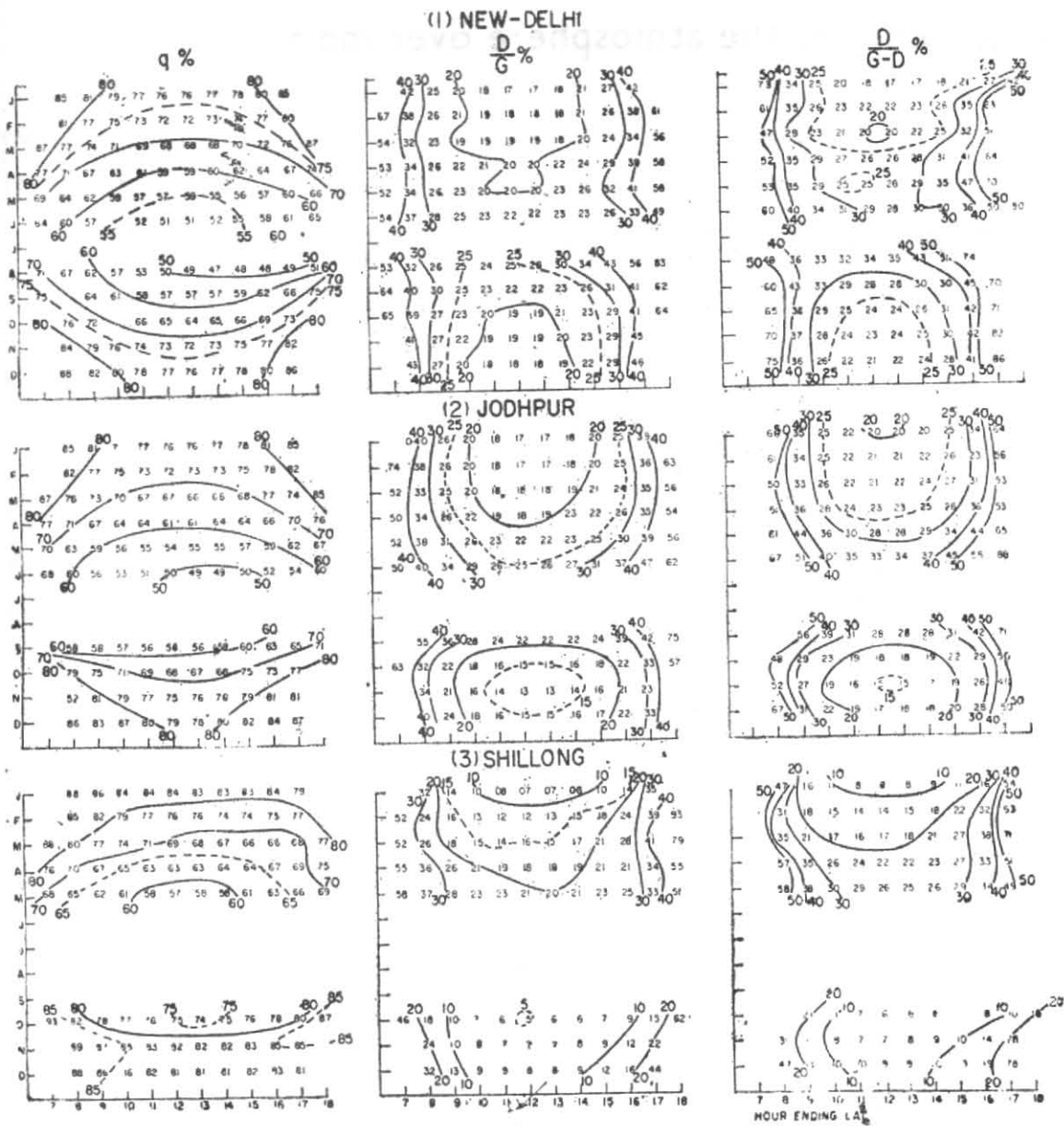
Fig. 1

TABLE 1
Maximum and minimum q, D/G and D/G—D (Percentage)

S. No.	Station	Lat. Deg. Min N	Long. Deg. Min E	Ele-va-tion (m)	Max q %	Month	Min q %	Month	Max-Min q	Max D/G %	Month	Min D/G %	month	Max-Min D/G	Max D/G—D %	Month	Min D/G—D %	Month	Max—Min D/G—D
1	New Delhi	28° 35′	77° 12′	216	77	Dec	51	Jun	26	25	Aug	17	Jan	8	55	Aug	17	Jan	18
2	Jodhpur	26 18	73 01	224	79	Dec	49	Jun	30	25	Jun	13	Nov	12	33	Jun	15	Nov	18
3	Shillong	25 34	91 53	1600	83	Jan	57	May	26	21	May	7	Jan	14	25	May	8	Jan	17
4	Ahmedabad	23 04	72 38	55	75	Dec	55	Jun	20	20	Jun	14	Nov	6	25	Jun	17	Nov	8
5	Calcutta	22 32	88 20	6	70	Jan	47	May	23	30	May	20	Oct/Nov/Dec	10	43	May	24	Nov	19
6	Bhavnagar	21 45	72 11	5	75	Dec	54	Jun	21	21	May	14	Dec	7	27	May	17	Dec	10
7	Nagpur	21 06	79 03	310	74	Dec	52	Jun	22	22	Jun	14	Dec	8	29	May/Jun	16	Dec	13
8	Bombay	19 07	72 51	14	71	Dec	47	May	24	31	Apr	17	Nov	8	45	May	15	Nov	30
9	Poona	18 32	73 51	559	75	Dec	57	Jun	18	18	Jun	12	Dec	6	23	Jun	14	Dec	9
10	Visakhapatnam	17 43	83 14	3	72	Dec	49	May	23	26	May	13	Nov	13	35	May	15	Nov	20
11	Goa	15 29	73 49	55	77	Dec	58	May	19	19	Apr/May	13	Dec	6	23	Apr/May	14	Dec	9
12	Madras	13 00	80 11	16	77	Dec	51	Jun	26	23	Jun	11	Dec	12	29	Jun	13	Dec	16
13	Trivandrum	8 29	76 57	64	69	Dec/Jan	55	Apr	14	22	Apr	14	Dec	8	28	Apr	17	Dec	11

$$m \approx \frac{1}{\sin h} \quad \text{for } h \text{ greater than } 20°.$$

Since the average monthly means have been utilised, 'sin h' has been calculated for the middle day of the month, every mid-hour local apparent time or true solar time. As the radiation values are very small, the results of computations are not reliable for very low solar elevations. Such values have been omitted.

4. Observations

Isolines depicting the variations of q, D/G and $D/G—D$ with time and season for the thirteen stations, viz.. New Delhi, Jodhpur, Shillong, Ahmedabad, Calcutta, Bhavnagar, Nagpur, Bombay, Poona, Visakhapatnam, Goa, Madras and Trivandrum are given in the Figs. 1-4. Given below are a few general observations :

(i) 'q' of the atmosphere is higher in the morning, decreases towards noon and increases again in the afternoon. This could be due to increasing convectivity towards noon.

(ii) 'q' is high in clear winter season but decreases towards summer as the aerosol or dust content of the atmosphere increases. After the rainy season, due to the washout by rain, the transparency increases again.

(iii) The ratio D/G and $D/G—D$ also decreases from morning to noon and increases towards the evening. This is so because of the lower and lower depth of the atmosphere through which the sun's rays have to pass through or airmass 'm' as the sun is more and more near the zenith.

(iv) The seasonal variation of these ratios show a similar but opposite trend to that of 'q' with the minimum generally in November. In December 'm' in high, more so for the northern stations, as the sun is farthest to the south.

The details of the stations, the maximum and minimum values, and their variations are presented in Table 1.

The Indian atmosphere is most transparent in December/January, the clear winter. The highest value of 83% is at Shillong in January. This is a hill station, generally characterised by a clear atmosphere. Also the airmass 'm' is least. Most of the north Indian stations are having a transparency of about 75% this time, probably because of moisture and winds caused by northeast monsoon bringing in aerosol. The next lowest is Calcutta which is well known to be a highly industrialised and polluted city.
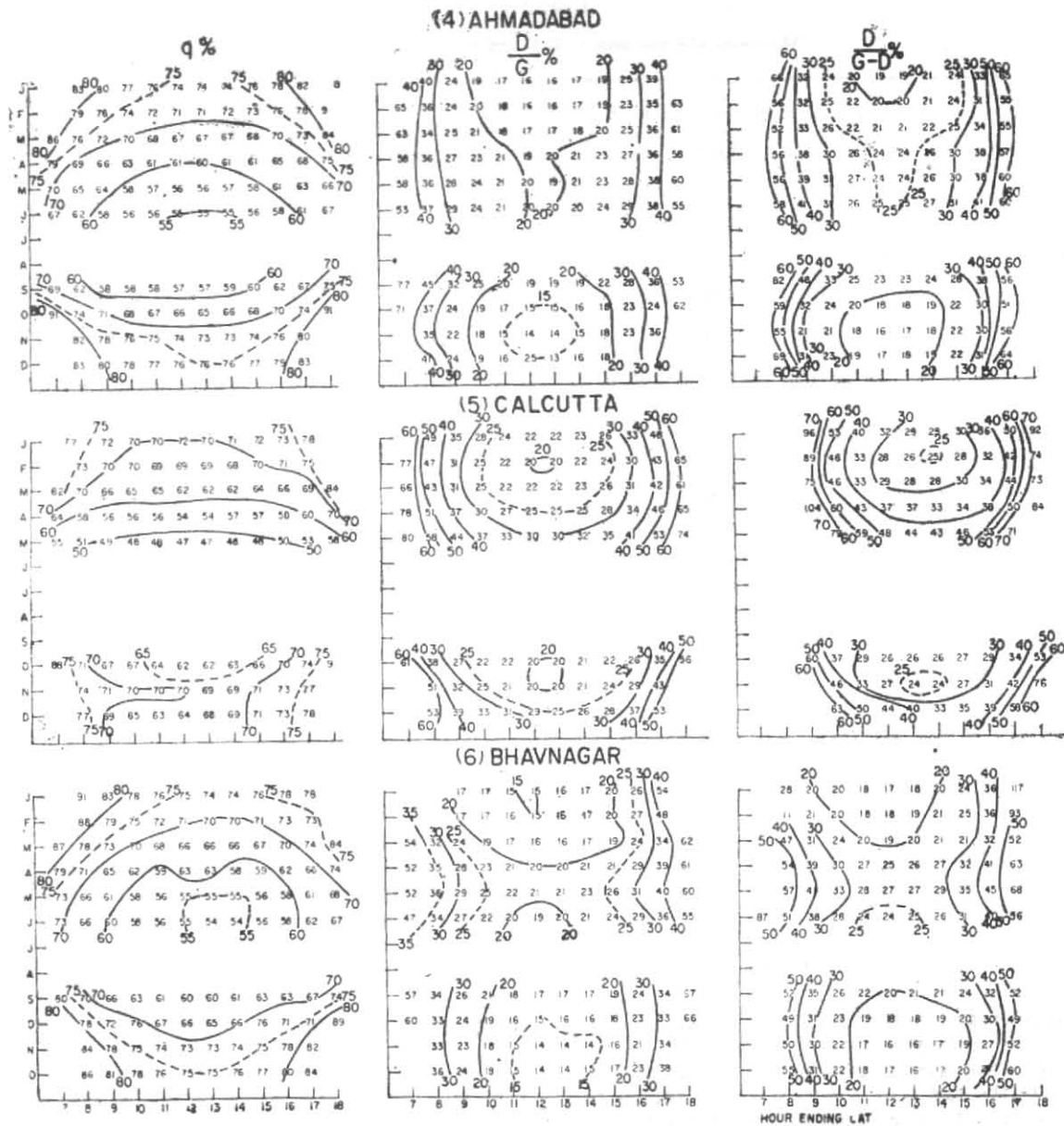
Fig. 2

The least transparency of the Indian atmosphere occur mostly in May/June just before the onset of monsoon as the aerosol content is very high whereas it occurs in April in Trivandrum, probably due to the summer convective activity which is maximum this time at the station. The lowest value of 47% occurs in the well polluted cities Bombay and Calcutta in May. Next value of 49% at Visakhapatnam could be due to high pollution. 51% is the transparency at New Delhi because of its dusty atmosphere due to its proximity to the semi-arid region.

The variation of 'q' is high, 30% at Jodhpur, which is in the semi-arid zone. In highly polluted cities the variations are low, viz., 18% in Poona, 20% in Ahmedabad and 23% at Calcutta. The least variation of 14% is

at Trivandrum, where the seasonal variation of temperature and moisture is the least. This station experiences the strong winds of both southwest and northeast monsoons.

The values of D/G and $D/G-D$ represent the scattering. Naturally, $D/G-D$ is higher than the ratio D/G. Due weightage has to be given to the airmass while discussing these ratios. The highest value is at the polluted Calcutta, followed by Visakhapatnam and the semi-arid Jodhpur and the proximate New Delhi, mostly, in May/June. It is in August at Delhi because the monsoon sets is later than other parts of the country and the rainfall is not much.

These ratios are the least generally in winter months. The least value of 7% is in Shillong, the hill station
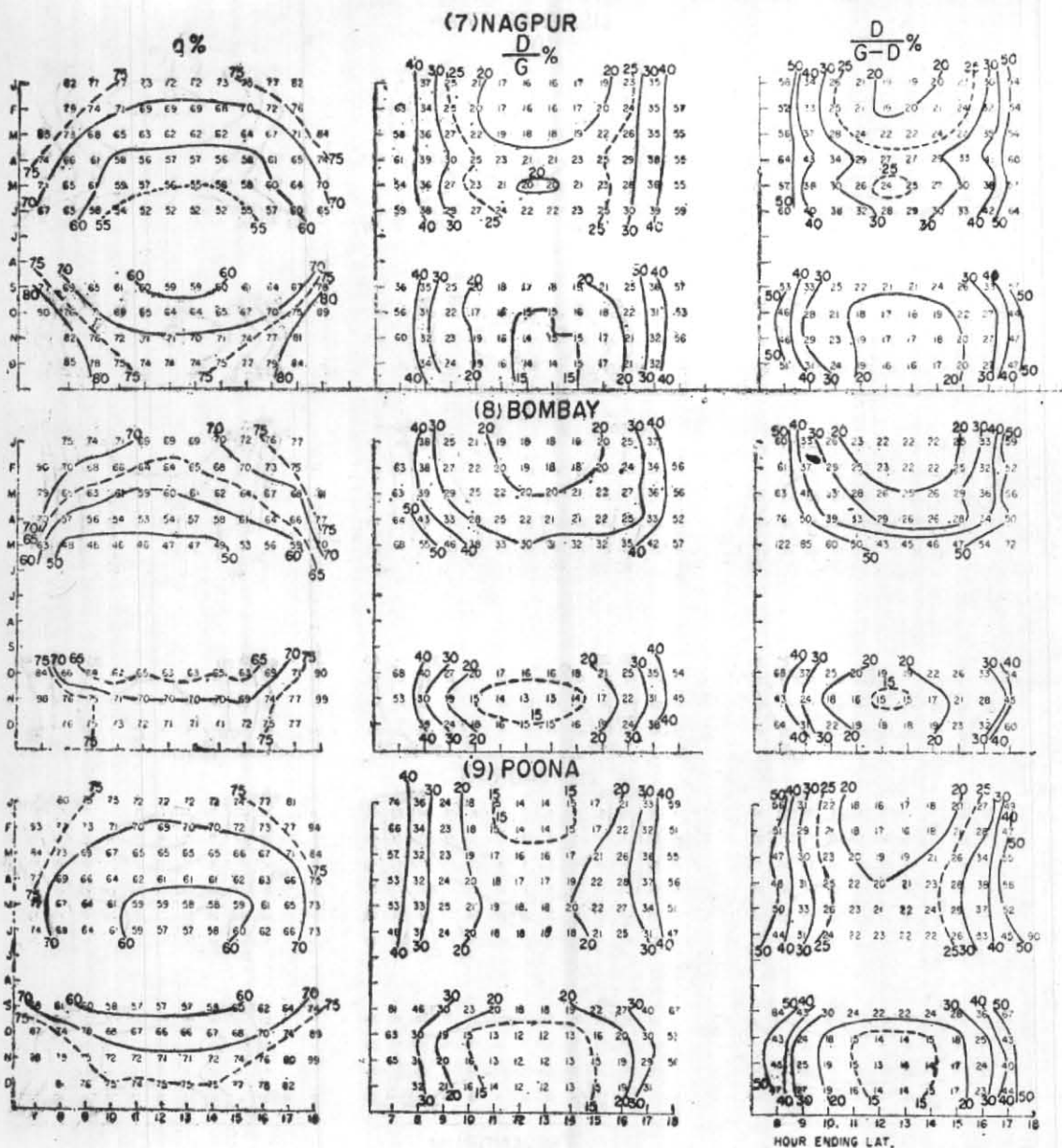
Fig. 3

characterised by the clear and thin atmosphere. The low values of D/G and $D/G—D$ are more or less same in Shillong.

The variation between maximum and minimum values of D/G is generally low at coastal stations.

A discussion on the relative variations on q and turbidity coefficient β is not being attempted since this has been dealt for a few stations in some of the papers under reference, especially on Jodhpur.

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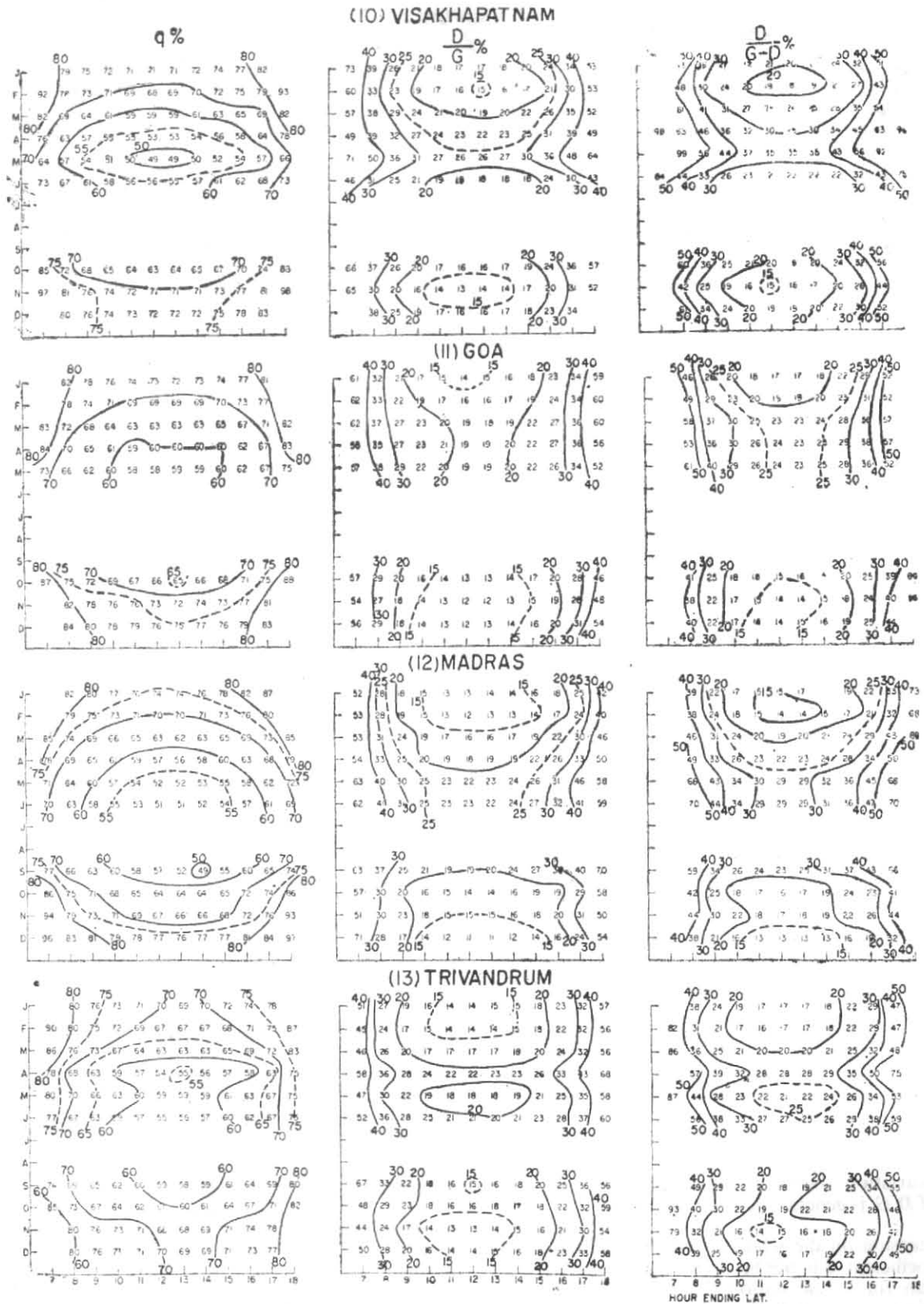
Fig. 4

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